C. [a] Not only by many of the markings already described, but especially by more vivid and extensive marks upon the shoulders, sides and flanks:—Zebra, wild asses, antelope, giraffe, hunting-dogs, etc.

[b] By special marking of the legs and feet upon the outside:—Zebra, antelope, etc.

D. [a] By most of the lateral and caudal markings already mentioned.

[b] By different colors, according to sex:—Night-hawks and other Caprimulgidæ.

[c] By difference in extent or shape of markings, according to sex:—Antelope, etc.

E. By various spots and lines, appearing only in the younger stages:—Deer, some swine, some Felidæ, etc.

SYNOPSIS OF ROSENBUSCH'S NEW SCHEME FOR THE CLASSIFICATION OF MASSIVE ROCKS.

BY W. S. BAYLEY.

ACCORDING to the new scheme for the classification of massive rocks, proposed by Professor H. Rosenbusch of Heidelberg in the second edition of his "Mikroskopische Physiographie der Massigen Gesteine," these are divided into three great groups, (I) intrusive rocks, (II) vein rocks, and (III) effusive rocks. The fundamental notion underlying this classification is briefly as follows: the structure possessed by rock masses as we find them in the earth is dependent upon two circumstances—(1) the chemical composition of their original liquid magmas, and (2) the conditions under which these magmas cooled. The effect of chemical composition upon the structure assumed by a rock magma in its passage to a solid state has not been definitely ascertained. Results recently obtained by Lagorio, however, indicate that the composition of the unsolidified portions of rock masses, exerts much more influence upon the final structure of the rock than has hitherto been supposed. The rapidity with which a rock cooled, as well as the conditions under which this took place, have long been known to be quite influential in determining its structure. Those rocks which cooled

slowly under great pressure and at great depths, where crystallization was gradual and undisturbed, assumed a granular aspect. Those which cooled quickly under low pressure became glassy. Those which began to crystallize in the depths of the earth, and continued their crystallization after the transference of their entire mass to other places, took on a porphyritic habit. Since, then, the structure of a rock indicates with some degree of certainty the prevailing conditions under which it was formed, it affords a convenient basis for the foundation of rock classification. And further, since the conditions under which a rock is formed are directly connected with its geological relations to surrounding rocks, the most logical classification is that which takes primarily into consideration these relations as the causes which produce the effects noted as structure.

Rosenbusch begins, then, by separating all massive rocks into the three great groups mentioned above. The intrusive or plutonic rocks are those which formed at great depths (Tiefen-gesteine); the effusive or volcanic rocks are those which flowed out upon a land surface and there solidified (Erguss-gesteine), and finally the second group, the vein rocks, are those which have been found only in veins or dykes in other rocks, and which may or may not be connected with the effusives.

Before discussing the classification in detail it will be necessary to define a few terms introduced by Rosenbusch to facilitate the description of the more prominent structures characterizing rocks, as we find them to-day.

A rock composed entirely of crystalline minerals is said to be *holocrystalline.* When it consists entirely of an unindividualized, structureless mass, it is known as *amorphous.* When it is partly amorphous and partly crystalline, *i.e.*, contains crystals in a hyaline ground-mass, the structure is described as *hypocrystalline.*

An *idiomorphic* mineral is one whose form is determined by the crystallizing forces acting within itself. An idiomorphic mineral is bounded by crystal planes. An *allotriomorphic* mineral is one which possesses a form due to the action of external forces, and not to the action of intramolecular forces. An allotriomorphic mineral is not bounded by its own crystal planes. Of two contiguous minerals in a rock, one idiomorphically developed, and the other allotriomorphically developed, the former is the older, compelling

the latter to assume a form which it would not do were it free to obey the forces at work within itself, tending to bound it with certain definite crystal planes.

A mineral is described as occurring in but *one generation* in a rock when all of its individual members have separated out continuously in the same interval of the rock's formation. When a portion of the individuals have separated out during one interval, and then, after other minerals have crystallized, another portion has separated, the mineral is said to occur in *two generations*.

When the constituents of a rock occur in but one generation, the rock is *granular* in structure. When but a small portion of these are idiomorphically developed, the rock is *hypidiomorphically granular*. When a relatively large portion or all of the constituents are idiomorphically developed, the rock is *panidiomorphic*. When none of the constituents are so developed the structure is *allotriomorphically granular*.

A *porphyritic* rock is one which contains one or more minerals in more than one generation.

I. Intrusive Rocks.

The intrusive or plutonic rocks are those which were formed at great depths. They were intruded between other rocks which existed before them, either as bosses or sheets, which never reached the surface, or they are the deep-seated portions of large masses which may have flowed out upon the surface of the earth. They may have been formed at any geological age, but are only found in the oldest portions of the globe, because only in these portions has sufficient time elapsed to allow of their exposure by erosion.

They are characterized by the possession of a hypidiomorphic granular structure, although in certain cases, where these rocks were intruded as flows between others, they sometimes tend to the panidiomorphic development.

They are divided, according to their chemical and mineralogical compositions, into eight families.

A. The Granites.

The granites are composed essentially of quartz and an alkaline feldspar, and one or more of the minerals of the mica, amphibole or pyroxene groups, sometimes tourmaline, and almost universally certain apatite, zircon and iron oxides.

They are divided into three divisions, as follows:—

1. TRUE GRANITES, containing both light- (muscovite) and dark-colored micas (biotite, etc.), including
   (A) *lithionite granite*, in which the dark ingredient is a lithium mica.
   (B) *luxullianite*, in which tourmaline replaces the lithionite.
2. GRANITITES, containing a biotite as its only micaceous constituent, including
   (A) *lithionite granitite*, with a lithium mica as the prominent micaceous constituent.
   (B) *amphibole granitite*, containing an amphibole in addition to biotite.
   (C) *augite granitite*, in which an augitic mineral is present.
3. AMPHIBOLE GRANITES, containing amphibole in place of the biotite of the granitites.

B. THE SYENITES.

Syenite differs from granite in the entire or almost entire absence of quartz as an essential constituent. The syenites besides contain no primary muscovite, but do contain a greater or less amount of plagioclase. The alkaline feldspars embrace, in addition to orthoclase, both albite and anorthoclase to a subordinate degree.

They are divided into:—

1. TRUE SYENITES, or hornblende syenites, composed of orthoclase, hornblende, and usually a little biotite.
2. MICA SYENITES, which often contain albite in addition to orthoclase and biotite.
3. AUGITE SYENITES, in which a monoclinic augite and orthoclase constitute the essential components.

C. THE ELÆOLITE SYENITES.

The elæolite syenites are quartz-free combinations of orthoclase and elæolite with one or more of the iron-bearing minerals of the pyroxene, amphibole or mica groups. With these is almost always associated some plagioclase and a greater or less amount of sodalite.

Their structure, though usually granular, sometimes becomes porphyritic through the occurrence of feldspar, elæolite and sodalite in two generations. It is probable that this structure is con-

fined to the outer edges of large masses and dyke forms of the kroc. The various occurrences of elæolite syenite are not well enough characterized to admit of a further classification.

D. THE DIORITES.

The diorites may be defined as rocks composed of plagioclase and biotite or hornblende, with or without quartz. Orthoclase and microcline sometimes accompany the plagioclase, and in certain cases augite partly replaces the biotite or hornblende. The structure of the diorites departs somewhat from the typical structure of the intrusive rocks in that the plagioclase and the biotite, amphibole and augite are sometimes idiomorphically developed.

The diorites are divided into:—

1. MICA DIORITES, in which biotite predominates over hornblende, including
   (A) *mica diorite,* which is quartz-free.
   (B) *quartz, mica diorite,* which is quartz-bearing.
2. DIORITES, in which hornblende is the most prominent colored constituent, including
   (A) *diorite,* and
   (B) *quartz diorite.*
3. AUGITE DIORITES, containing a large amount of augite, including
   (A) *augite diorite,* and
   (B) *quartz-augite diorite.*

E. THE GABBROS.

The gabbros are combinations of plagioclase and a monoclinic or an orthorhombic pyroxene, with or without olivine.

Their structure varies slightly from the typical granular structure, in that the plagioclase occurs in broad lath-shaped crystals.

They are divided, according to the nature of their pyroxenic constituents into:—

1. GABBROS, which contain, as their pyroxenic constituent, diallage, or a monoclinic augite with a composition approaching that of diallage.

   The gabbros include

   (A) *gabbro* proper, which is olivine-free, including two varieties:

(*a* 1) hornblende gabbro, in which diallage is partly replaced by hornblende, and

(*a* 2) hyperite, containing a little olivine and some orthorhombic pyroxene.

(B) *Olivine gabbro,* olivine-bearing.

2. NORITES, which contain an orthorhombic augite as the principal pyroxenic component.

The norites are divided, according as to whether they contain olivine or not, into

(A) *norite,* and

(B) *olivine norite.*

F. THE DIABASES.

The diabases are composed essentially of plagioclase and augite, with or without olivine and quartz.

They form a well-marked class among the intrusive rocks, which differs in many respects from the other intrusives, and approaches very near in characteristics to some of the effusives. This is due principally to the fact that the diabases occur as dykes and intruded layers between sedimentary beds, and thus tend to assume in some degree the structure possessed by sheets which have cooled on the surface under atmospheric pressure alone. They are frequently accompanied by tufas, and they often possess amygdaloidal upper surfaces. Since, however, the pressure under which they were formed was much greater than that under which the volcanic rocks were produced, and, as we may suppose, their cooling much more gradual, the diabases are holocrystalline and hypidiomorphic-granular, as distinguished from the hypocrystalline and porphyritic structures of the members of the effusive class. Nevertheless, the tendency of the plagioclase to assume idiomorphic forms is so strong that an approach to the porphyritic structure is noticeable in many diabases. As among the gabbros, the first differentiation of the diabases is dependent upon the presence or absence of olivine as an essential constituent.

1. DIABASES are olivine-free combinations of plagioclase and augite, usually with a little hornblende and mica.

(A) *diabase* proper contains no quartz.

(B) *quartz diabase* contains quartz as a primary component, including

(*b* 1) sahlite diabase, which contains an idiomorphic colorless monoclinic pyroxene (sahlite), and

(*b* 2) enstatite diabase, containing an orthorhombic augite.

(c) *teschenite* is analcite-bearing.

2. Olivine Diabases contain olivine as an essential constituent in addition to plagioclase and augite.

G. THE THERALITES.

The theralites, foımerly called teschenites, are intended to embrace rocks composed of plagioclase and nepheline, together with the accessories angite, biotite and olivine. Rocks of this composition are not known to exist among the intrusives, unless certain basic rocks from Montana, lately described by Mr. Wolff, belong here. Corresponding members of the effusive class are, however, quite well known, and it is therefore expected that true theralites will be found at some time in the future, even if the Montana rocks should turn out not to belong in this family.

H. THE PERIDOTITES.

The peridotites are the most basic of the intrusive rocks. They contain no plagioclase, but usually do contain a large amount of olivine and a mineral of the amphibole or pyroxene families. Their bisilicate constituent is made use of for purposes of sub-classification.

1. Picrite is composed of olivine and augite.
2. Amphibole Picrite contains olivine and hornblende.
3. Wehrlite consists of olivine and diallage.
4. Harzburgite is a combination of olivine and a rhombic pyroxene.
5. Lherzolite contains olivine, diallage and a rhombic pyroxene.
6. Dursite consists of olivine and chromite.

II. Vein Rocks.

The class of vein rocks includes those which exist as independent geological bodies only in the form of veins or dykes, although many similar rocks occur also as facies of certain intrusive and effusive rocks. This class is not as well defined as either the intrusive or the effusive class. Rosenbusch personally is inclined to place them

with the intrusives, but since no direct connection has been traced between them and deeply buried rock masses, of which they may be regarded as a part, he decides to place them in a separate group until more knowledge of their relations has been obtained.

The structure of the vein rocks resembles in some respects that of the intrusive rocks, and in others that of the effusives. Three well-marked types are recognizable: the granitic, the granite-porphyry, and the lamprophyre. Since these three types can be distinguished macroscopically, and are very characteristic, they are made use of to separate the vein rocks into three groups, which are in turn subdivided into families, according to mineralogical constitution, as in the class of intrusive rocks.

II. A. The Granitic Vein Rocks.

The structure of the granitic vein rocks differs from that of the intrusive rocks, in that their individual constituents tend to become idiomorphic. In most cases this tendency has gone so far as to produce a rock, all of whose components are bounded by their own crystal outlines. They are then panidiomorphic-granular. An approach to the porphyritic development is sometimes the result of a repetition of conditions which allows of the separation of some of the constituents in two generations.

The granitic vein rocks include:—

1. Aplite, or muscovite granite, consisting of orthoclase, quartz and muscovite.
   (a) *pegmatite* is a coarse-grained aplite.
   (b) *beresite* is orthoclase-poor aplite.

II. B. The Granite Porphyry Group.

The structure characteristic of this group of rocks is the holocrystalline-porphyritic. Their ground mass is a granular aggregate of crystalline minerals. The predominant porphyritic crystals are light in color, *i.e.*, they are neither iron nor magnesia bearing. The occurrence of iron and magnesia-bearing minerals as porphyritic constituents is exceptional.

The group is divided into:—

A. The Granite Porphyries.

The mineralogical composition of this family is the same as that

of the granites. The porphyrytic constituents are quartz, orthoclase, and usually one or more of the granitic minerals, biotite, hornblende, augite or muscovite. The same minerals occur also in the ground mass.

No attempt is made to divide the granite porphyries, although it may be convenient to separate them into:—

1. GRANITE PORPHYRY proper, containing no muscovite, and
2. ELVAN muscovite—rich varieties.

B. THE SYENITE PORPHYRIES.

The syenite porphyries differ from the granite porphyries in the absence of quartz from among the porphyritic crystals. In all other respects they are similar to them. Quartz occurs in the groundmass, and plagioclase is more common than in the granite porphyries.

They are divided, according to their principal iron-bearing constituent, into:—

1. HORNBLENDE SYENITE PORPHYRY, which contains orthoclase and hornblende as the most prominent porphyritic constituents.
2. MICA SYENITE PORPHYRY, in which orthoclase and biotite occur in porphyritic crystals.
3. AUGITE SYENITE PORPHYRY, in which augite is the most important non-feldspathic porphyritically developed component.

C. THE ELÆOLITE SYENITE PORPHYRIES.

The elæolite syenite porphyries usually contain elæolite as the most important porphyritic constituent after orthoclase. In one or two cases the elæolite is found only in the groundmass. Rocks belonging to this family have not been sufficiently studied to admit of further classification.

D. THE DIORITE PORPHYRITES.

The diorite porphyrites are not very widespread. They consist of plagioclase, hornblende, and sometimes quartz and biotite as porphyritic crystals in a groundmass composed principally of plagioclase and quartz.

They are divided into families, in accordance with the existence or non-existence of quartz among the porphyritic crystals.

D. *a*. DIORITE PORPHYRITES.

1. DIORITE PORPHYRITE contains plagioclase and hornblende as porphyritic constituents.
2. MICA DIORITE PORPHYRITE contains plagioclase and biotite in porphyritic crystals.

D. *b*. QUARTZ DIORITE PORPHYRITES.

1. QUARTZ DIORITE PORPHYRITE contains plagioclase, quartz and hornblende as the porphyritic ingredients.
2. QUARTZ MICA DIORITE PORPHYRITE. In the rocks of this class biotite takes the place of the hornblende in the quartz diorite porphyrites.

II. E. THE LAMPROPHYRE GROUP.

The lamprophyre group differs from the granite porphyry group of vein rocks in that the iron and magnesium-bearing silicates, hornblende, pyroxene and biotite are the most important constituents occurring in two generations. Their feldspar, which may be either orthoclase or plagioclase, occurs in but one generation.

In composition they resemble the syenites and diorites of the intrusive rocks, and are therefore divided in accordance with this resemblance.

A. SYENITIC LAMPROPHYRES.

The syenitic lamprophyres consist of an alkaline feldspar, biotite, hornblende and pyroxene as essential constituents.

They possess both the panidiomorphic-granular and the holocrystalline-porphyritic structure. The former sometimes passes over into the hypidiomorphic-granular.

They are subdivided according to the presence or absence of biotite as a prominent constituent.

1. MINETTES contain biotite as the principal iron-bearing constituent, both in the granular and the porphyritic forms.
   - (A) *hornblende minettes* contain hornblende in addition to biotite.
   - (B) *augite minettes* have augite besides biotite as a prominent constituent.

(*b* 1) olivine minette is an augite minette containing olivine.

2. VOGESITES contain hornblende or augite as the most important colored constituent.
   (A) *hornblende vogesite.* In this, hornblende predominates over augite.
   (B) *augite vogesite* possesses augite in larger quantity.

B. DIORITIC LAMPROPHYRES.

The dioritic lamprophyres differ from the syenitic lamprophyres in containing plagioclase instead of an alkaline feldspar in addition to biotite, amphibole and augite.

Like the syenitic varieties, these rocks are also developed with the panidiomorphic granular and the holocrystalline porphyritic structures.

Their separation into two classes also depends upon the greater or less amount of biotite in their composition.

1. KERSANTITE. This rock is characterized by the possession of large amounts of biotite.
   (A) *Aschaffite* contains quartz and feldspar in addition to the iron-bearing minerals in porphyritic development.
   (B) *Olivine kersantite* contains olivine in addition to the essential constituents of the kersantite.
      (*b* 1) *pilite kersantite,* in which the olivine has been altered to pilite.
2. CAMPTONITE contains hornblende in place of the biotite of the kersantites.

(TO BE CONCLUDED.)